WHITE PAPER

SILVER SPRING NETWORKS

CONNECTING SMART GRID & CLIMATE CHANGE

Michael Jung and Peter Yeung, Silver Spring Networks

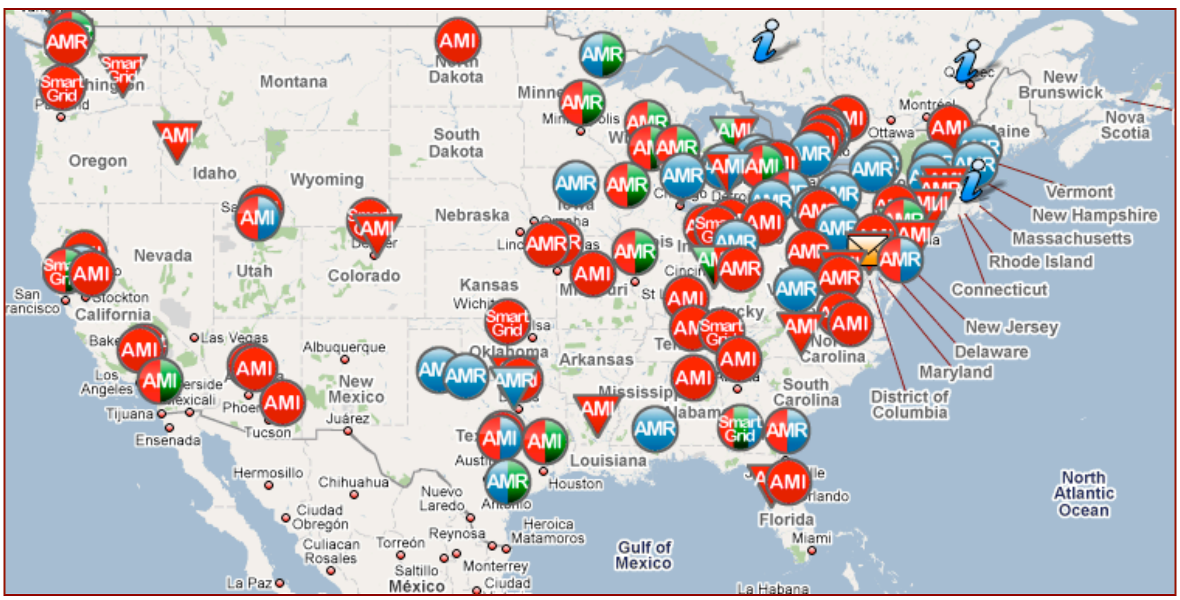
Introduction

Utilities across the country are embarking on the deployment of smart grid technologies. They are motivated by the need to modernize aging infrastructure, improve efficiency, and empower customers. In addition to these benefits, smart grid deployments present significant opportunities to further leverage these investments to reduce greenhouse gas emissions by 5-9% from 2005 levels and deliver 0.7 gigatons of CO2e GHG reductions that amount to nearly one-quarter of the Waxman-Markey targets for 2030. A network-first approach to deploying unified smart grid networks lowers costs and accelerates application deployment. Such sizable reductions depend on smart grid network connectivity and can be realized through improved energy efficiency and conservation; increased integration of utility-scale and distributed renewable generation; and large-scale penetration of vehicle electrification that displaces oil with electric power.

In this context, the smart grid emerges as a critical tool to address global climate change. This paper is divided into four sections. The first section will size up smart grid deployments that are taking place today and that can be expected to further accelerate in coming years. The second section will explore some of the driving forces behind smart grid deployments and examine the role of climate change. The third section will identify and quantify specific mechanisms through which a forward-thinking smart grid can help address climate change. The fourth and final section will recommend policy actions to ensure that smart grid infrastructure being built today delivers maximum climate benefits.

Smart Grid Deployments Are Underway

Across the country and around the world, electric utilities are embarking upon the most sweeping modernization of the power grid in a century through the deployment of smart grid technologies. Already, some 30% of the nearly $40B market for advanced metering infrastructure (AMI) in the US has been contracted, and major deployments representing millions of smart meters are underway at several large electric utilities across the country, including Pacific Gas & Electric (5.1m customers), Florida Power & Light (4.5m customers), Southern Company (4.4m customers), and Centerpoint (2.5m customers). Moreover, scores of AMI pilot projects are in process with dozens of additional utilities, the results of which will set the stage for further AMI rollouts to an even larger population of US customers in the coming years. The image below, taken from the *Smart Metering Projects Map* on Google Maps, illustrates the geographic diversity of initiatives around one smart grid application, advanced metering.



Of course, the smart grid involves much more than just advanced metering. The potential market for smart grid-networked distribution automation (DA) is anticipated to approach 12 million devices, and leading utilities such as AEP (5.2m customers) and Duke Energy (4m customers) are actively investigating and testing smart grid-enabled DA technologies. 34 States, including DC, have implemented various renewable generation requirements and goals that could lead to significant intermittent generation, both distributed and utility scale. Smart grid-enabled plug-in hybrid electric vehicles (PHEVs) are poised to potentially grow into a sizable share of the 251 million registered passenger cars and trucks in the US.

The American Recovery and Reinvestment Act of 2009 allocated $4.5 billion to further accelerate smart grid investment and deployment, over $2 billion for electric vehicles, and over $13 billion for renewable generation. Hundreds of applications have been submitted for projects worth tens of billions, and reportedly 431 applications representing $24.6 billion in projects were submitted in the first round of the $3.4 billion Smart Grid Investment Grant Program alone.[1] This sizable Federal funding complements roughly $1.3 billion of venture capital investment in the smart grid sector since 2005.[2]

As quickly as the smart grid is growing today, there is much more to come. The smart grid represents one of the largest and fastest-moving markets for clean technology investments, with estimates that it will be worth $20 billion annually within five years and $100 billion overall.[3] With active competition between new entrants and established firms for market share and technology leadership, the smart grid will usher in unprecedented modernization of the electric power system with far-reaching implications and long-lasting ramifications.

Climate Change Influences, But Does Not Drive, Smart Grid Investment

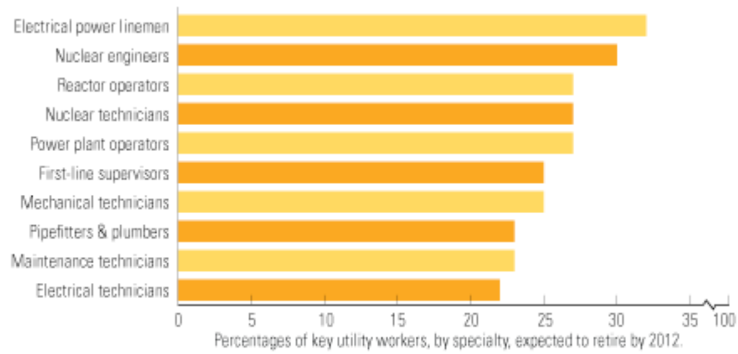
Several factors are motivating this wave of smart grid investment. However, climate change is only one of many key factors driving investment. While the benefits that can be generated by smart grid technologies differ considerably for each utility, depending on such variables as energy prices, labor costs, and geography, a number of smart grid-addressable issues can be identified that are common to most, if not all, US utilities.

One aspect is the need to modernize aging utility infrastructure and automate the utility sector's aging workforce. At the distribution level, various estimates put the average age of distribution assets, such as transformers, at or above the engineering lifetime for which these assets were designed. At the transmission level, it is widely acknowledged that the system originally built for one-way, utility-specific, localized energy delivery is increasingly stressed by the need to serve as the infrastructure behind today's two-way, multi-utility, regional power markets. At the generation level, the vast fleet of US power plants that were put into operation in the 1950s and 60s is fast approaching the end of its operating life as these facilities face mounting challenges to generating reliable,

[1] Anecdotal information obtained from confidential industry sources
[2] David J. Leeds, *The Smart Grid in 2010: Market Segments, Applications, and Industry Players*, Greentech Media, July 2009
[3] *Cisco Outlines Strategy for Highly Secure 'Smart Grid' Infrastructure,* Cisco press release, 18 May 2009

affordable, and environmentally-sound electricity. Looking at the utility workforce, the US Department of Labor estimates that 20-30% of utility workers in key areas, such as line mechanics, are expected to retire by 2012 (see figure below). Given the challenges and gaps the utility industry faces in educating, hiring, training, and retaining skilled employees, smart grid-enabled automation presents an attractive solution to being potentially strapped for the experienced workers necessary to operate a largely analog, electromechanical electricity system.

Expected Utility Workforce Retirements



1. Brain drain. A large percentage of utility workers are expected to retire in the next few years. Even more are eligible for retirement. Source: U.S. Department of Labor

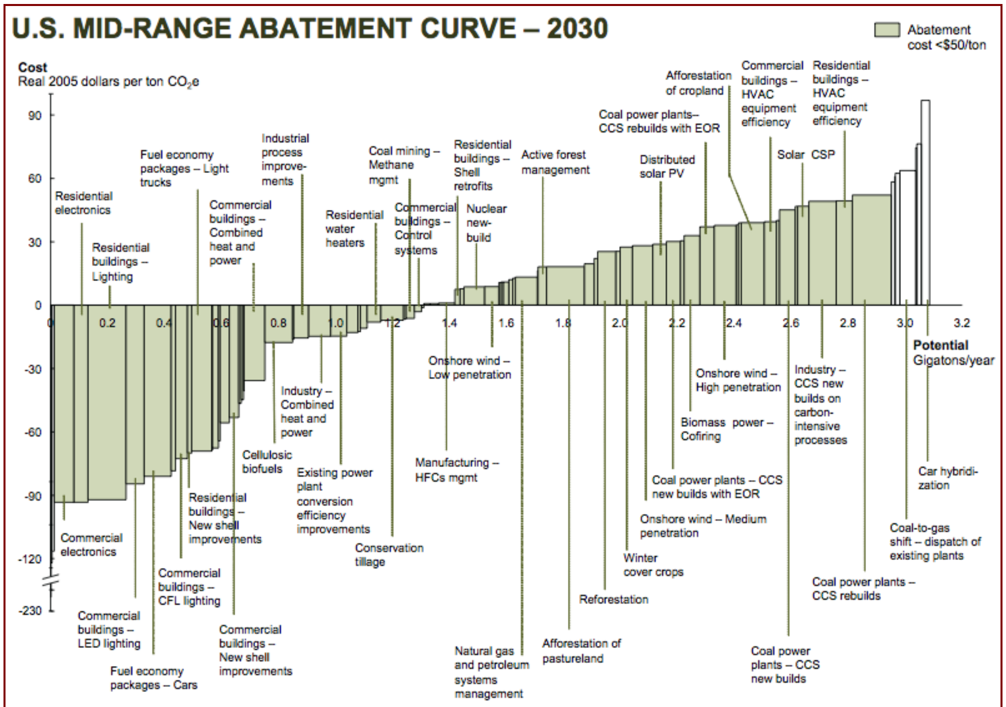
* Chart excerpted from article downloaded on 27 August 2009 from Power Magazine online (http://www.powermag.com/business/ The-aging-workforce-Panic-is-not-a-strategy_73.html)

The need to improve energy efficiency also is helping to drive smart grid deployments. Thanks to uncertainties surrounding future environmental regulation and market structure, many utilities are motivated (and sometimes incentivized) to avoid and/or delay new capital investments in new power generation assets. In order to buy additional time, utilities can increase system load factor and extract additional value from their existing assets. In recent years, there has been rising external pressure from the political sector, the investor community, and customers themselves for utilities to embrace energy efficiency for the environmental benefits of lowering fuel consumption and reducing environmental emissions.

Empowering consumers is a third driver for the smart grid. Utilities today recognize that a growing number of their customers are now able to respond to, and may even begin to demand (particularly as energy costs rise), product options that vary in terms of price per kilowatt-hour, risk of price volatility, and “greenness” of environmental attributes. This has taken place through increased numbers of green rates, bill smoothing options, and TOU pricing. Going forward, there will be an increasing array of smart grid enabled technologies (web portals, in home displays, PCTs) that empower consumers to make better decisions about their energy use.

Clearly, a diverse range of operational, economic, and market factors are driving utility smart grid investments. Where does global climate change fit in? While many of the potential benefits arising from smart grid technologies could help reduce greenhouse gas (GHG) emissions, the environmental challenges posed by global climate change do not appear to be a high-priority consideration as smart grid investments are being made. Both utility smart grid plans and regulatory frameworks put forth by utility regulators generally stop short of explicitly coordinating smart grid-enabled technologies to maximize GHG reductions, largely due to a lack of a GHG price mechanism or mandate in the US.

This is particularly concerning, in light of the fact that reducing GHG emissions enough to achieve climate stabilization, or even just to meet the Waxman-Markey goal of reducing US GHG emissions by 3 gigatons CO2e by 2030, will require aggressive implementation of the full range of potential abatement opportunities. No single technology or abatement opportunity can avert climate change. McKinsey & Company has produced a GHG abatement curve (see figure below) that illustrates the many GHG reduction opportunities that can be achieved at less than $50/ton CO2e. Several of these abatement technologies either require or will greatly benefit from smart grid infrastructure to be effective at scale.



Source: McKinsey analysis

*Chart excerpted from *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, downloaded on 27 August 2009 from McKinsey.com (http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf)

Leveraging the Smart Grid to Reduce GHG Emissions

We have shown that smart grid deployments are underway, and we have revealed that the forces motivating smart grid deployment reasons include, but are not necessarily driven by, climate change. This section will identify specific ways through which the smart grid can help achieve reductions amounting to 5-9% of total 2005 US GHG emissions.

Utilities play an important role in national climate policy, representing approximately 40% of total US GHG emissions. Although electric power generation accounts for the vast preponderance of utility sector GHG emissions, options for directly reducing GHG emissions from utility power plants, such as carbon capture and sequestration (CCS) or new nuclear generation, are limited, expensive, and largely unproven. In order to buy time for significant advances in generation technology to become more cost-effective and lower-risk, downstream GHG reductions in the energy delivery infrastructure are required.

Cost-effective downstream GHG reduction opportunities can be facilitated by the smart grid by boosting energy efficiency (in both grid efficiency and end-use conservation), as well as enabling greater integration of renewables (in both utility-scale projects and distributed generation). Additionally, smart grid infrastructure also can be leveraged to enable widespread transport electrification, which not only confers dramatic GHG reduction benefits due to the favorable emissions profile of traditional generating plants - and certainly of renewable power - over internal combustion engines, but also serves to enhance US energy security and trade balances by reducing the need for imported petroleum.

Smart Grid enables more economic reduction of GHG than without Smart Grid

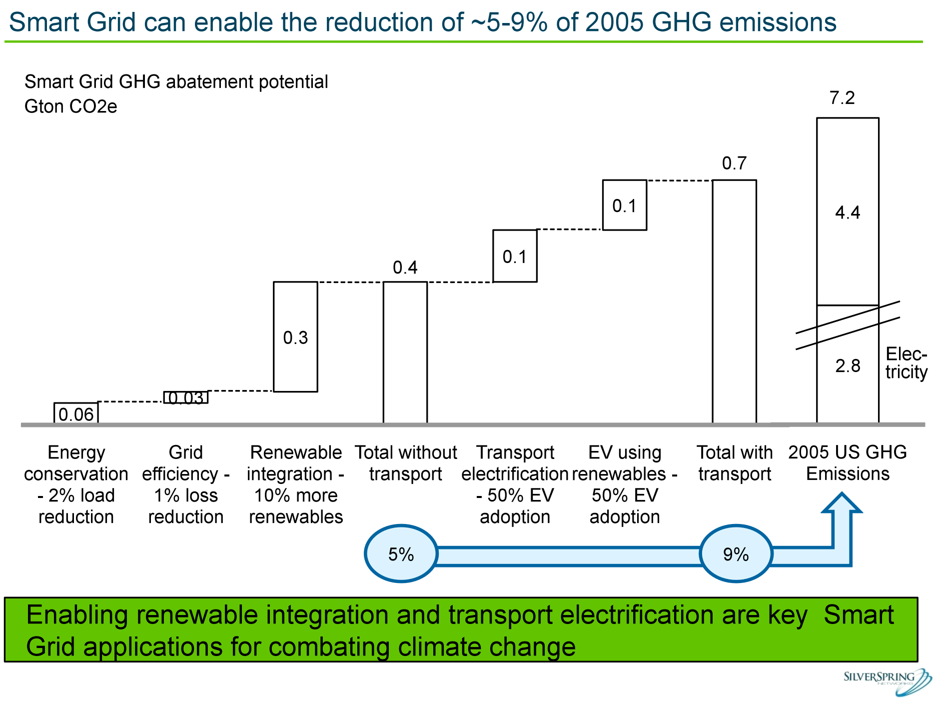
	How SG enables	Potential impact	Without SG
Energy conser-vation	• Provides more real time feedback on energy usage • Home Area Network enables information	• Studies show 5-15% energy usage reduction	• Only monthly feedback (bill), or next day (with AMI only)
Grid efficiency	• Distribution Automation allows for Volt-VAR optimization and reduction of line losses	• Initial utility pilots show 1-2% baseload improvements, more during peak	• Utilities generally pre-program cap banks seasonally
Renewable integration	• Demand Response creates active loads to follow renewables • Distribution automation provides voltage stabilization	• Renewables impact the grid ~20% of load • DR of 15-20% could allow ~10% more renewables	• Utilities need to build more generation to firm renewables
Transport Electrifi-cation	• DA can prevent local distribution problems from large EV load draws • Manages peak demand with DR applications	• Electric motors are more efficient than ICE, allowing for greater efficiency, even with coal	• Utilities need to build more generation to handle additional peak load
EV with renewables	• Allows for Smart Charging of EV's to firm renewable generation • Can be used as ancillary services	• Drives to zero GHG fuel if charging is flexible with renewable production	• Utilities fuel EV's with coal and natural gas

The smart grid enhances end-use energy conservation by providing real-time feedback on energy usage and using home area networks to communicate time-sensitive price information to customers. Numerous studies have shown a demonstrable and persistent reduction of 5-15% in electricity consumption due to price awareness alone, which is approximately doubled by availability of easy-to-use, set-it-and-forget-it enabling technologies, such as programmable communicating thermostats and HAN-enabled smart appliances. Smart grid-enabled metering also makes possible continuous building commissioning, which alone can yield overall energy savings of 15% (EPRI 2008). With time, richly-detailed energy consumption data generated by the smart grid will allow for highly-accurate targeting of energy efficiency investments toward those buildings that will deliver the greatest benefits. We expect that a two percent reduction in end-use energy consumption that is enabled by smart grid deployment can deliver 0.06 gigatons of CO2e GHG reductions.

Smart grid infrastructure can improve grid efficiency to reduce line losses by networking distribution automation devices (e.g. – capacitor banks) to minimize reactive power flows through adaptive voltage control (i.e., Volt-VAR optimization). Conservatively estimating 1% reduction energy losses from smart grid-enabled distribution automation translates into at least 0.03 gigatons of CO2e GHG reductions.

Renewables stand to benefit dramatically from the smart grid. Using smart grid-enabled demand response (via direct load control and pricing programs) to create active loads to balance intermittent generation reduces risks and optimizes load shapes for utility-scale wind and solar power projects. Furthermore, reliable smart grid networking of distributed renewables is essential for utilities to identify and manage the grid impacts (e.g. - safety risks to line workers, voltage changes) posed by decentralized power generation. Both utility-scale and distributed renewables benefit from smart grid-networked energy storage, which can help turn renewable generation from being price-takers to becoming price-setters in energy markets. We estimate that these smart grid-enabled mechanisms can facilitate an additional 10% of renewable generation in the overall generation mix by 2030, delivering 0.3 gigatons of CO2e GHG reductions.

Electric vehicles (EVs) present a powerful opportunity for the electric grid to reduce US GHG emissions significantly by displacing internal combustion with electric power. Potential has been identified to reduce US carbon emissions significantly through vehicle electrification, utilizing off-peak power generation and energy delivery capacity to charge plug-in electric vehicles. Such time-sensitive charging will require smart grid connectivity to manage the sizable power draw of EV's so as to minimize grid impacts by ensuring that charging only takes place off-peak. A single EV that is charging can draw load comparable to two central air-conditioning units, making a neighborhood of two-EV-owning homes more than capable of exceeding the capacity of existing transformers, if everyone plugged in when they got home in the evening around the same time, creating a need for smart grid (ie – DA) solutions to address this issue. Additionally, smart grid networking will be necessary if EVs are to take full advantage of off-peak renewable power generation (e.g., wind power that predominantly blows at night in many US regions) instead of traditional fossil-fuels, thereby maximizing the potential GHG reduction benefit of vehicle electrification by effectively eliminating carbon emissions from EV transportation. Assuming 50% EV penetration, we project 0.1 gigatons of CO2e GHG reductions from smart grid-enabled vehicle electrification, which can be doubled to 0.2 gigatons CO2e, if EVs are charged using power from renewable generation.



Cumulatively, these opportunities can reduce US GHG emissions by 0.7 gigatons CO2e. This represents nearly one-quarter of the 3 gigatons CO2e reduction from 2005 GHG emissions levels targeted by 2030 in the Waxman-Markey American Clean Energy and Security Act of 2009. While some of these GHG-reducing opportunities, such as end-use conservation and Volt-VAR optimization, may be possible to implement to some extent without true smart grid connectivity, all of these applications will benefit from and can be maximized through deployment and utilization of the smart grid.

Policy Recommendations

The smart grid can serve as a versatile foundation to help the electric sector to reduce GHG emissions by 0.7 gigatons CO2e, equivalent to nearly one-quarter of the Waxman-Markey proposal's 2030 targets. What policies are necessary to ensure that we fully harness the smart grid's potential to achieve these reductions? We propose that building utility smart grids through a network-first approach upon unified network platforms can help achieve these reductions more quickly and at lower cost.

Network-first: Although most people are naturally excited by the prospect of smart grid devices and applications, at the core of the smart grid must reside communications and computing technology that enables utilities to enjoy insight into what is happening at every node of their network at any given moment. A network-first approach to regulatory consideration of smart grid deployment prioritizes the performance, interoperability, and longevity of smart grid networking technologies, which serve as a foundation for related and subsequent investments in smart grid devices and applications (primarily AMI as the driver of building the network platform today). Key topics in each of these categories include:

Performance

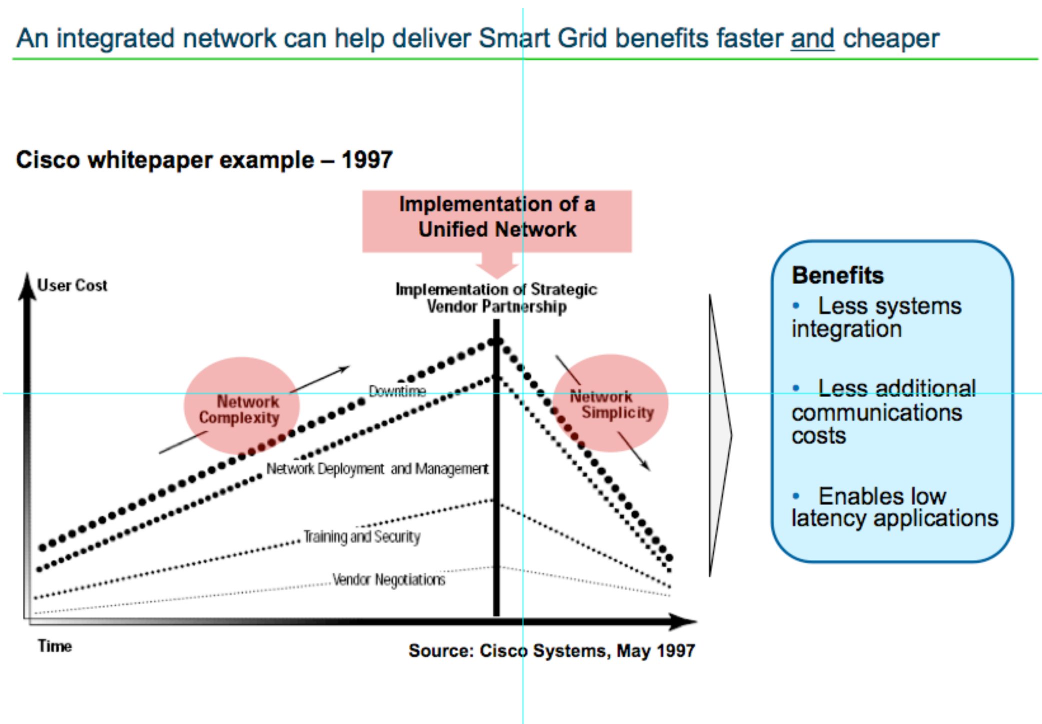
- Endpoint data rate and network capacity: How much is enough? At what cost? Can it be expanded over time?
- Latency: How fast does the network need to be to enable the most time-sensitive foreseeable application?

Interoperability

- To what extent does the network utilize proven networking standards, such as Internet Protocol? How well does it adhere to emerging NIST smart grid interoperability standards?

Longevity

- How many decades does the network's threat model factor in for security design? How effectively, quickly, and securely can firmware be upgraded to incorporate security improvements?
-



Unified networks: Rather than building out a separate network infrastructure for each category of devices for each new application, there are substantial benefits to be gained for utilities by building out their smart grids upon a unified network platform. The figure above illustrates the benefits of unified networking, as learned firsthand from the emergence of the Internet, and these lessons should be applied to the next big network infrastructure that our country builds, the smart grid. Not only are cost savings made possible by avoiding redundant communications systems, but the deployment of new applications and devices is vastly accelerated. Also, integration of back office systems for smart grid applications can be a critical bottleneck in delivering these new utility functions; unifying core communications platform and using open, standards based approaches (e.g., Internet Protocol) can help utilities deliver these programs more quickly and efficiently, leading to deeper and swifter GHG reductions than otherwise would be possible without unified smart grid network infrastructure.

Conclusion

Untapped opportunities exist to better leverage current and forthcoming smart grid deployments to more effectively reduce US GHG emissions by 5-9% of 2005 levels, an amount equal to approximately 0.7 gigatons, or nearly one-quarter of the Waxman-Markey goal, by 2030. These smart grid GHG reduction opportunities include improved energy efficiency, reduced line losses, better renewables integration, and vehicle electrification. Adopting a network-first approach and building smart grid with a unified network platform will position smart grid deployments to take swift and full advantage of these GHG reduction opportunities.

Recommended Resources

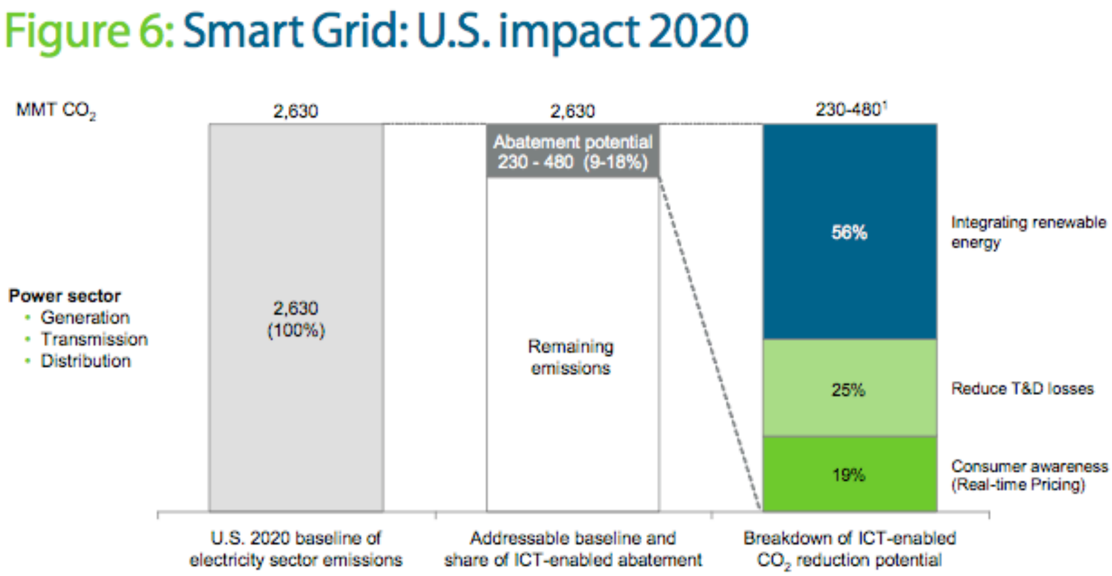
This paper benefits from and builds upon a number of studies that have explored the connection between smart grid and GHG emissions.

The Electric Power Research Institute (EPRI) issued a June 2008 report (Technical Update 1016905), *The Green Grid*, which projects that 60-211 million metric tons of CO2 could be avoided through smart grid-enabled technologies by 2030. The following table taken from this report summarizes EPRI's analysis:

Table 10-1
Smart Grid Energy Savings and Avoided CO_2 Emissions Summary (2030)

	Emissions-Reduction Mechanism Enabled by Smart Grid	Energy Savings, 2030 (billion kWh)		Avoided CO_2 Emissions, 2030 ($Tg\ CO_2$)	
		Low	*High*	*Low*	*High*
1	Continuous Commissioning of Large Commercial Buildings	2	9	1	5
2	Reduced Line Losses (Voltage Control)	4	28	2	16
3	Energy Savings Corresponding to Peak Load Management	0	4	0	2
4	Direct Feedback on Energy Usage	40	121	22	68
5	Accelerated Deployment of Energy Efficiency Programs	10	41	6	23
6	Greater Integration of Renewables	--	--	19	37
7	Facilitation of Plug-in Hybrid Electric Vehicles (PHEVs)	--	--	10	60
	Total	**56**	**203**	**60**	**211**

The Global e-Sustainability Initiative (GeSI) commissioned Boston Consulting Group to produce a US-oriented report on how information and communication technologies can reduce GHG emissions, issued in November 2008. *Smart2020: Enabling the Low Carbon Economy in the Information Age, United States Report Addendum,* uses a framework established in a global report previously issued by McKinsey and Company and includes analyses of how smart grid can reduce US GHG emissions by 2020. The following figure from this report summarizes the results of Boston Consulting Group's projections, which estimate that 230-480 million metric tons of CO2 could be avoided through smart grid-enabled technologies by 2020:



Plug-in electric vehicles are included, albeit very conservatively, in the EPRI analysis, and they are not factored in at all into the GeSI study. A much more detailed analysis of the technical potential for PHEVs to reduce US GHG emissions can be found in a November 2007 report, *Impacts Assessment of Plug-In Electric Vehicles on Electric Utilities and Regional U.S. Power Grids- Part 1: Technical Analysis,* issued by Michael Kintner-Meyer Kevin Schneider, and Robert Pratt of the Pacific Northwest National Laboratory (PNNL). The PNNL study estimates that a shift to smart grid-enabled PHEVs could reduce US petroleum imports by as much as 52% and lower US GHG emissions of the light duty fleet by up to 27%.